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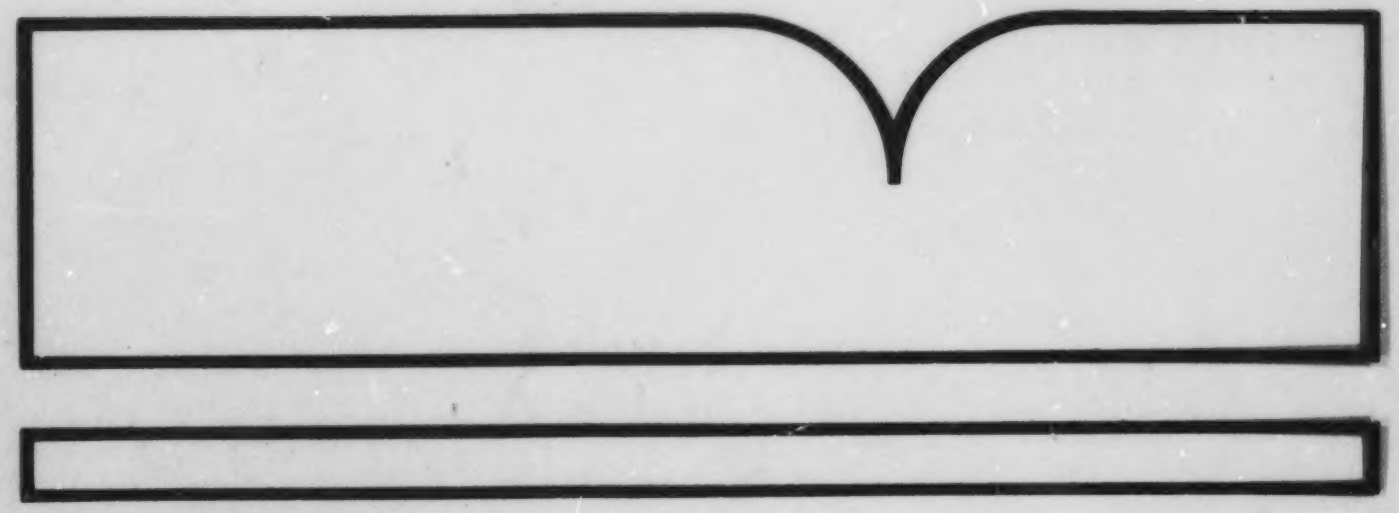

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16. ABSTRACT The paper addresses the problem of relating measurements of polycyclic organic matter (POM) in source emissions to the potential hazard associated with the total POM in the sample measured. Although uncertainties exist in these quantitative measurements of POM, a more serious problem concerns the relation of hazard to a given mass and composition of POM. As used here, hazard is defined as the quantity that may be used to indicate the relative environmental problems of various source emissions. For each individual type of POM source, both benzo(a)-pyrene--B(a)P--and total POM provide excellent indicators of hazard, evaluated by a weighted sum of concentrations. The method of using a linear combination of masses of the individual POM compounds to model hazard due to POM is shown to be appropriate under certain conditions, and to follow directly from a simple probabilistic model of the physical and chemical events leading up to a response event. The results suggest that, in most cases, total POM measurements provide somewhat more consistent hazard prediction than those of B(a)P. In view of this, the total POM indicator should be more useful in predicting hazard for sources for which the compound-specific composition of POM emitted is not well known.

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Mathematical	Stationary Sources	12A
Aromatic Polycyclic Hydrocarbons	Polycyclic Organic Matter (POM)	07C 14B
Prediction		
Measurement		
Toxicity	Potential Hazard	06T
Pyrenes	Benzo(a)pyrene	

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1.a

INDICATORS OF HAZARD FOR POLYCYCLIC ORGANIC MATTER

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INTRODUCTION

This paper addresses the problem of relating measurements of polycyclic organic matter (POM) in source emissions to the potential hazard associated with the total POM in the sample measured. The POM component usually occurs as a small fraction of the total particulate matter. Although small on a mass basis, the POM fraction comprises a large number of individual POM compounds, some of which are known to be hazardous while others are known to be nonhazardous. Quantitative relations between POM measurements and a potential hazard are central to the POM environmental assessment problem. Development of such quantitative relations has been limited by the current sparse data base on source POM and the lack of dose/response data for the large number of compounds detected in sources. However, there is a need to know how these measurements correlate with potential hazard in order to have an effective environmental protection program.

Traditionally, measurement of one or several individual POM compounds in a sample has been used to indicate the degree of hazard associated with the total POM. More recently, gas chromatography and mass spectrometry techniques to measure a multitude of individual POM compounds have been developed and used to characterize source and ambient POM.(1) Also, an inexpensive and rapid screening method has recently been developed, based on sensitized fluorescence, to estimate the total mass of polycyclic aromatic hydrocarbons, a subset of POM compounds, in an environmental sample.(2) For the purpose of environmental assessment, each of the above measurement techniques provides an indicator of the potential hazard which would be due to the combined effect of all POM in a sample.

Although uncertainties exist in these quantitative measurements of POM, a more serious problem concerns the relation of hazard to a given mass and composition of POM. As used here hazard is defined to be a quantity that may be used to indicate the relative environmental problems of various source emissions. The potent mutagenic and carcinogenic activity in laboratory bioassay systems is well known for a small number of specific POM compounds (e.g., benzo(a)pyrene and 7,12-dimethylbenzanthracene) as well as the nonhazardous properties of other, closely related POM compounds (e.g., benzo(e)pyrene and anthracene). However, estimating the hazard of a mixture of a large number of POM's contained as a small fraction of the particulate matter matrix involves a number of very tenuous assumptions, even if the pure compound composition is well defined. The effects of synergism and antagonism and the dominant mass of the non-POM matrix challenge any model that may be proposed to describe the environmental hazard of the mixture. Despite these considerations, it is natural to assume that a first order estimate of the relative hazards of different samples containing POM could be formulated from some linear combination of the masses of the individual POM compounds, weighted according to some specific measure of hazard for each POM compound. It should be emphasized that, for this model to be valid, the individual POM compounds involved must act independently (e.g., without synergism) in the mixture. In the discussion of linear measures of hazard, it is shown

that this linear combination approach follows if a very simple molecular response model is assumed.

The main results of this paper are concerned with correlations between hazards and proposed indicators in each of 12 available detailed studies of POM production from combustion sources. The data from the studies—which are noted in *Table 1*—were compiled and summarized in Reference (15). For each study, the hazard (as determined from the complete distribution of POM compounds and the various sets of weights) is correlated with each of the proposed measured indicator quantities, thus enabling the relative merits of these indicators to be evaluated.

TABLE 1

POM EMISSION SOURCE CATEGORIES

Study No.	Concentration units for B(a)P and POM	Source category	Reference
1	mg/kg wood	Residential wood combustion	3
2	mg/hr	Coke ovens	4
3	μg	Asphalt hot mix plants	5
4	mg/m^3	Ferroalloy plant	6
5	μg	Tangential oil-fired utility boiler	7
6	ng/m^3	Ambient air—New York City	8
7	$\mu g/Nm^3$	Coal combustion—all scales	9
8	μg/ml	Jet engine exhaust	10
9	μg/g fuel	Laboratory forest fires	11
10	$\mu g/m^3$	Coal, oil, and bark industrial boilers	12
11	ng/g	Coal-fired utility boiler	13
12	$\mu g/Nm^3$	Utility boilers and residential furnace	14

Finally, for clarity the following precise terminology will be used throughout. The term *hazard probability* will refer specifically to the probability of a response. The term *hazard* will mean a quantity which is directly proportional to the hazard probability and constructed by the linear models discussed below. Although a hazard quantity defined in this way cannot, of course, predict the specific degree of health hazard on the basis of POM measurements for a given sample, such a definition is used here for the purpose of comparing the relative merits of indicators of POM-related hazard. Note that because of the direct proportionality between hazard probability and hazard quantity, the same correlations are obtained between indicators and either this hazard quantity or the hazard probability. This has particular advantage since it is unnecessary to know the actual value of the proportionality constant in order to compare the relative merits of the various indicators.

DISCUSSION

Linear Measures of Hazard

The effort to describe the hazard, or hazard probability, is clearly hampered by the wide variety of possible mechanisms by which such responses may be triggered. The

situation in which a "threshold" exists is widely different from that in which damage is caused by cumulative effects of small concentrations over extended periods.

In view of this, it is not to be expected that any particular type of model for hazard probability will be universally valid. However, as will now be seen, there are common situations in which such a model is natural and can be related to simple molecular events.

The classical dose-response curve represents the probability that a given response (disease onset, death, etc.) will be produced by specified amounts of an administered dose. Obviously this concept may be used also where the dose is not instantaneously administered but results from constant exposure over some fixed period of time. The shape of such a dose-response curve for a given compound may vary widely—leading to a variety of commonly used analyses such as "probit" and "logit"[16] where the overall curve shape is important. For the purposes of this analysis, however, the shape of the curve is of most interest for small dosage values (in the sense of concentrations presenting acceptably small response probabilities). At such concentrations the dose-response curve is commonly linear—or nearly so.

Specifically, this assumed linearity requires that the probability of a response by an individual, to a concentration ϱ of a given compound, be simply $K\varrho$, where K is a constant whose value depends, among other things, on the particular compound. For a mixture of n compounds with concentrations ϱ_i, and corresponding constants K_i, the response probability (assuming independent action of the compounds) is $1 - \prod_{i=1}^{n} (1 - K_i\varrho_i)$ which is approximately $\sum_{i=1}^{n} K_i\varrho_i$ if each response probability $K_i\varrho_i$ is small (as assumed). The constant K_i corresponding to the i'th compound may be termed the hazard (or response probability) per unit of concentration of that compound, and the total hazard probability is the weighted linear sum $\sum_{i=1}^{n} K_i\varrho_i$.

The constants K_i refer, of course, to some *fixed* (say, unit) exposure duration. However, the response probability will often be (closely) proportional to exposure duration, so that varying exposure durations may then be accounted for by writing K_iT instead of K_i, for a period of length T (or $K_i \int_0^T \varrho_i dt$ if the concentration ϱ_i changes with time).

The above demonstration of the linearity of hazard probability as a function of concentrations was based primarily on *assumed* linearity of the dose-response curve for small doses. However, it should be noted that such linearity actually follows from simple physical considerations if each molecule of compound has some (presumably minute) probability p of causing a response, and the molecules act independently. For the probability of a response caused by at least one of N molecules present is then

$$1 - (1 - p)^N \cong 1 - e^{-\gamma}$$

if $Np = \gamma$. Note that for small γ, $(1 - e^{-\gamma})$ is close to the value γ. But N is, by definition, proportional to the concentration ϱ, so that the response probability of the compound is indeed $K\varrho$ for some constant K.

In view of the above discussion, it thus can be reasonable to assume a response probability of $\sum_{i=1}^{n} K_i \varrho_i$ for a mixture of n compounds. The constants K_i may also be interpreted as the inverses of acceptable levels for each compound. For a single compound, p_o is the maximum acceptable response probability; then the maximum acceptable concentration level is $\varrho = L$ where $KL = p_o$, so that $K = p_o/L$. Writing L_i for the maximum permitted level for each compound (and making the standard independence assumptions), it follows that the total hazard probability for the n compounds is

$$\sum_{i=1}^{n} K_i \varrho_i = p_o \sum_{i=1}^{n} \varrho_i / L_i$$

As noted above, a measure of hazard which is proportional to the hazard probability suffices for the later correlation studies. We therefore define the *hazard* to be the quantity

$$H = \sum_{i=1}^{n} k_i \varrho_i$$

where the k_i consist of dimensionless constants, or weights, proportional to the above K_i. The weight k_i is set for each compound indicating the relative potency between the compounds and leading to the hazard H which is measured in units of concentration and is directly proportional to the hazard probability. Since the actual weights are not precisely known it seems desirable to examine the effect of a variety of weighting systems. Three sets of such weights are used below—one assuming equal hazards from the potentially harmful POM compounds in a mixture, and the other two based in different ways on certain specific hazard ratings and "goal levels" which have been proposed for POM compounds.(15) The specific weights are described below.

Indicators and Their Correlation with Hazards

In accordance with the above discussion, we define a quantity H for a mixture of POM compounds as the linear combination $\Sigma k_i \varrho_i$ of the concentrations ϱ_i. In practice it may be convenient to measure just a few or even just one of the concentrations (that for B(a)P is commonly chosen) and to use a multiplicative factor to estimate H. One of the purposes of this study is to determine what that factor should be and how well the value thus predicted correlates with $H(=\Sigma k_i \varrho_i)$ or equivalently with the value of the hazard probability. Note once again that for this purpose the analysis does not require knowledge of the actual proportionality constant between the hazard probability and H.

In this connection, note that there is no prior reason for supposing that hazard can be well predicted simply as a multiple of concentration of one or more compounds. It might well be that a full linear (nonzero intercept) or nonlinear function would prove much more satisfactory. In fact, the case studies presented demonstrate that nothing significant is added to the prediction ability by using a full linear function, and that prediction by a simple multiple of the measured concentration generally gives excellent results. This has the incidental benefit of making easy comparisons between the (multiplicative) constants in different emission situations—comparisons which would otherwise be much more difficult in view of the disparate units used for the various cases.

The other major purpose of this work is to compare the prediction ability of a single compound indicator (here, the commonly used B(a)P) with that of prediction by the (easily measured) total POM concentration. Since the latter quantity includes nonharmful as well as harmful components, it is apparent that the relative prediction quality must depend on the circumstances involved. If most of the harmful content arises from B(a)P, B(a)P concentrations should predict hazard most effectively. On the other hand, the "total POM" indicator should be better if the mixture is composed of mainly harmful compounds, and not dominated by the single compound B(a)P. In fact (as will be apparent below), for the cases studied, both B(a)P and total POM provided excellent prediction; however, the latter gives the more consistent results (especially with low, or even zero, B(a)P).

The specific procedure involves constrained (zero intercept) and unconstrained regression studies for total hazard against the concentration of either B(a)P or total POM, for each of the 12 case studies mentioned above. The POM emission source categories for each of the 12 studies are given in Table 1. The total hazard has been computed in three different ways, writing H_1, H_2, H_3 in turn for the values of H in the respective weighting systems.

H_1: The sum of concentrations of known harmful (carcinogenic) POM compounds.

H_2: Weighted sum of harmful compounds giving weights 1-4 (as noted in Table 2) based on rankings of carcinogenicity obtained from Reference (15), B(a)P having weight 4.

H_3: Weighted sum as in H_2 except that B(a)P (weighted 4 in H_2) is weighted 16 in H_3.

Note that, because the weighting factors are dimensionless, the units for H_1, H_2, and H_3 are the same as the units of concentration of B(a)P or total POM (e.g., mg/kg wood). Although this does not address the problem of comparing the absolute hazard of POM arising from different circumstances (e.g., wood burning, urban air, jet engine exhaust), it does allow an evaluation of the extent to which the resulting prediction factors (b_1, b_2, and b_3) may be widely applied.

The purpose of the use of different weighting systems is primarily to test the robustness of the procedure to such change—since clearly there is currently considerable uncertainty and debate about the specific relative hazards of different compounds. It is reasoned that, if good prediction (correlation) is obtained for a variety of divergent weighting systems, then the quality of this prediction can be expected to be just as good for the more precise weights resulting from a more refined understanding of the effects of the individual compounds.

Hazard H_1 is clearly unrealistic in assigning the same weight to the potent carcinogen B(a)P, as to those which are regarded as involving minimal hazard. However, this is an extreme selection of weights for which the indicator B(a)P should be "at its worst," thus providing a lower limit for its prediction ability.

The computation of H_2 and H_3 uses weights which are likely to be more realistic, with increasing weight given to B(a)P. For H_3, B(a)P should be "at its best" as an indicator of POM hazard among the cases considered. Correspondingly, the prediction ability of the "total POM" indicator should range between that for its least favorable circumstance (H_3) and the best (H_1) among those considered. The specific rankings and weights are listed in Table 2.

TABLE 2

COMPOUND SPECIFIC WEIGHTINGS FOR POM HAZARD MODELS

Code No.	Compound	Hazard Model		
		H_1	H_2	H_3
1	Anthracene	1	1	1
2	Benz(a)anthracene	1	3	3
3	7,12-Dimethyl benz(a)anthracene	1	4	4
4	Dibenz(a,j)anthracene	0	0	0
5	Dibenz(a,h)anthracene	1	4	4
6	Dibenz(a,c)anthracene	1	1	1
7	Phenanthrene	1	2	2
8	Benzo(c)phenanthrene	1	3	3
9	Fluorene	0	0	0
10	Benzo(a)fluorene	0	0	0
11	Benzo(b)fluorene	0	0	0
12	Dibenzo(a,h)fluorene	0	0	0
13	Dibenzo(a,g)fluorene	0	0	0
14	Benzo(c)fluorene	0	0	0
15	Dibenzo(a,c)fluorene	0	0	0
16	Fluoranthene	1	1	1
17	Benzo(b)fluoranthene	1	2	2
18	Benzo(j)fluoranthene	1	1	1
19	Benzo(k)fluoranthene	1	2	2
20	Benzo(g,h,i)fluoranthene	0	0	0
21	Aceanthrylene	0	0	0
22	Benzo(j)aceanthrylene	0	0	0
23	3-Methyl cholanthrene	1	4	4
24	Naphthacene	0	0	0
25	Naphtho(2,1,8-qra)naphthacene	0	0	0
26	Pyrene	1	1	1
27	1-Methylpyrene	0	0	0
28	Benzo(a)pyrene	1	4	16
29	Benzo(e)pyrene	1	2	2
30	Dibenzo(a,l)pyrene	1	2	2
31	Dibenzo(a,h)pyrene	1	2	2
32	Dibenzo(a,i)pyrene	1	3	3
33	Dibenzo(a,e)pyrene	0	0	0
34	Dibenzo(cd,jk)pyrene	0	0	0
35	Indeno(1,2,3-cd)pyrene	1	2	2
36	Chrysene	1	2	2
37	Perylene	0	0	0
38	Benzo(ghi)perylene	0	0	0
39	Coronene	0	0	0
40	Indene	1	1	1
41	Naphthalene	1	1	1
42	Monoalkyl naphthalenes	1	1	1
43	Dimethyl naphthalenes	1	1	1
44	Acenaphthene	0	0	0
45	Methyl acenaphthenes	0	0	0

(continued)

TABLE 2

(Continued)

Code No.	Compound	Hazard Model		
		H_1	H_2	H_3
46	Acenaphthalene	0	0	0
47	Methyl acenaphthalenes	0	0	0
48	Methyl anthracenes	0	0	0
49	Dimethyl anthracenes	0	0	0
50	Trimethyl anthracenes	0	0	0
51	C_2-Alkyl anthracenes	0	0	0
52	Cyclopenta anthracenes	0	0	0
53	Methyl benz(a)anthracenes	0	0	0
54	C_2-Alkyl benz(a)anthracenes	0	0	0
55	Methyl naphthacenes	0	0	0
56	C_2-Alkyl naphthacenes	0	0	0
57	Methyl phenanthrenes	0	0	0
58	C_2-Alkyl phenanthrenes	0	0	0
59	Cyclopenta(def)phenanthrene	1	1	1
60	Methyl benzo(c)phenanthrenes	0	0	0
61	C_2-Alkyl benzo(c)phenanthrenes	0	0	0
62	Picene	1	2	2
63	Benzo(g)chrysene	1	1	1
64	Methyl fluorenes	0	0	0
65	Dimethyl fluorenes	0	0	0
66	Methyl fluoranthenes	0	0	0
67	Dimethyl fluoranthenes	0	0	0
68	3,4-Benzofluoranthene	0	0	0
69	Methyl benzo(b)fluoranthenes	0	0	0
70	Dimethyl benzo(b)fluoranthenes	0	0	0
71	Methyl benzo(j)fluoranthenes	0	0	0
72	Dimethyl benzo(j)fluoranthenes	0	0	0
73	Methyl benzo(k)fluoranthenes	0	0	0
74	Dimethyl benzo(k)fluoranthenes	0	0	0
75	Methyl benzo(ghi)fluoranthenes	0	0	0
76	Dimethyl benzo(ghi)fluoranthenes	0	0	0
77	Dimethyl pyrenes	0	0	0
78	Cyclopenta(cd)pyrene	0	0	0
79	Methyl benzo(a)pyrenes	0	0	0
80	Methyl benzo(e)pyrenes	0	0	0
81	Methyl chrysenes	1	2	2
82	C_2-Alkyl chrysenes	0	0	0
83	Triphenylene	0	0	0

RESULTS

It is illuminating to see the actual plots of hazard against each indicator. While space does not permit the reproduction of all cases, the graphs for 2 of the 12 studies (Studies 1 and 6) are given in Figures 1-12 at the end of this paper. These two studies were selected since they are the most comprehensive of the 12 and illustrate the general behavior found in most studies. Figures 1 and 2 show the unweighted hazard H_1 for Study 1 (wood combustion) plotted against B(a)P and total POM, respectively. Figures 3 and 4 repeat these plots with the weighted hazard H_2 (giving B(a)P weight 4) substituted for H_1, whereas Figures 5 and 6 plot H_3 where B(a)P has weight 16. An examination of these plots indicates high correlation between each hazard and each indicator with the total POM indicator showing a slightly better fit.

The same plots are made for Figures 7-12 for Study 6 (New York City ambient particulate matter). It will be seen that for the unweighted hazard, total POM is a clearly superior indicator to B(a)P. The same is true, but less pronounced, for the hazard H_2 where B(a)P has weight 4, whereas the situation reverses for H_3, with weight 16 for B(a)P. This illustrates the principle previously mentioned, that B(a)P will tend to be a better predictor in cases where it is either a substantial proportion of the harmful POM present, or is highly weighted in the hazard calculation.

While not all the cases show the same high degree of correlation, it is evident that within a specific emission source category, both B(a)P and total POM provide excellent predictors and that the regression lines do not appear to have intercepts which are significantly different from zero. The latter conclusion is borne out by full regression studies which clearly demonstrate that zero intercept is an appropriate assumption. Hence, the possibility of a full regression will not be considered further here. The regression lines for the constrained (zero intercept) regressions are plotted in Figures 1-12. The correlations between hazard and indicator, and the slopes of the lines are given in Table 3. To be specific, the predictor of hazard H_i is $H_i = b_i\varrho$, where ϱ is the indicator concentration (in whatever units have been used) and b_i is the desired multiplicative factor (regression line slope) to give the predicted hazard value H_i (i = 1, 2, or 3).

Discussion of Hazard Prediction Factors

The above results indicate that the hazard due to POM emissions *from a specific source category* can be estimated by applying an empirically determined multiplicative factor (b_i) to either B(a)P or total POM. However, as can be seen from Table 3, the values of b_i's are different for each source category. The ranges for the b_i's as well as other statistics for b_i's are summarized in Table 4. Consequently, when estimating the hazard of POM emissions, it is desirable to use a b_i derived from existing data for the *same source category.* Unfortunately, the detailed POM analysis necessary for derivation of the b_i's is often not available for POM source categories of interest. Therefore, to predict hazard from either B(a)P or total POM, an appropriate b_i needs to be selected.

One approach to estimating a b_i for either B(a)P or total POM is to use data from the source category whose characteristics most closely approach those of the source of interest. This has the advantage of utilizing information on source characteristics to narrow the choice of b_i, but likewise the disadvantages of requiring knowledge of source characteristics as well as a data base of source specific b_i's from which a source with an acceptable "fit" can be found. Furthermore, the effect of different source

TABLE 3

MULTIPLICATIVE FACTORS (AND CORRELATION COEFFICIENTS) FOR PREDICTION OF H_1, H_2, and H_3 BY B(a)P AND BY TOTAL POM

	b_1		b_2		b_3	
Study	B(a)P	POM	B(a)P	POM	B(a)P	POM
1	62(0.98)	0.70(0.99)	101(0.97)	1.14(0.99)	113(0.98)	1.27(0.99)
2	103(0)	0.90(0.99)	123(0)	0.90(0)	136(0)	0.99(0)
3	922(0.73)	0.65(0.99)	1,430(0.73)	1.00(0.99)	1,440(0.74)	1.01(0.99)
4	—[a]	0.74(1.0)	—[a]	1.40(1.0)	—[a]	1.40(1.0)
5	30(0.78)	0.80(0.99)	52(0.82)	1.35(0.99)	64(0.91)	1.50(0.99)
6	3.4(0.77)	0.83(0.99)	9.4(0.85)	2.18(0.98)	21(0.98)	4.62(0.88)
7	55(0.78)	0.88(0.99)	168(0.76)	2.49(0.97)	168(0.78)	2.62(0.97)
8	87(0.96)	0.91(0.99)	117(0.99)	1.23(0.99)	129(0.99)	1.34(0.99)
9	38(0.99)	0.73(0.99)	72(0.99)	1.39(0.99)	84(0.99)	1.61(0.99)
10	90(0.78)	0.70(0.99)	173(0.80)	1.33(0.99)	185(0.82)	1.40(0.99)
11	2.5(−)[b]	0.55(−)[b]	6.0(−)[b]	1.33(−)[b]	18(−)[b]	4.00(−)[b]
12	—[a]	0.97(0.99)	—[a]	1.20(0.99)	—[a]	1.20(0.99)

[a]No B(a)P detected.
[b]Insufficient data to compute correlation.

TABLE 4

SUMMARY OF PREDICTION FACTOR STATISTICS

	Model	
	$H_i = b_i \times$ [B(a)P]	$H_i = b_i \times$ [POM]
Unweighted Case (H_1)		
Range of b_1	2.5-922	0.55-0.97
$\bar{b}_1$	139	0.78
s.d.(b_1)[a]	277	0.12
cv[b]	1.99	0.15
Weighted Case (H_2)		
Range of b_2	6.0-1,430	0.90-2.49
$\bar{b}_2$	225	1.41
s.d.(b_2)[a]	427	0.46
cv[b]	1.90	0.33
Weighted Case (H_3)		
Range of b_3	18-1,440	0.99-4.62
$\bar{b}_3$	236	1.91
s.d.(b_3)[a]	427	1.20
cv[b]	1.81	0.63

[a]Standard deviation.
[b]Estimated coefficient of variation ($= \text{s.d.}(b_i)/\bar{b}_i$).

characteristics on the b_i's is unknown.

A second approach to estimating hazard from B(a)P or total POM is to use a single or universal multiplicative factor for all source categories. This would be more appealing for the cases where little is known about the source characteristics, or for which extensive POM distribution data (that could be used to derive b_i's) do not exist. In this situation, the use of some universal multiplicative factor b_i applied to a value for total POM would be preferred over the use of the corresponding b_i applied to a value for B(a)P. This is because the range of b_i's is narrower for the total POM-hazard models vis-a-vis the B(a)P-hazard models, as can be readily seen in Table 4. Note that, to normalize the scale for comparison of the dispersion of the b_i's, for B(a)P with the b_i's for total POM, the coefficient of variation (cv) has been employed. Comparison of the cv's for the B(a)P multiplicative factors with the cv's for the total POM multiplicative factors again indicates that the latter are preferred when estimating the hazard for POM emissions from new sources.

CONCLUSIONS

For each individual type of POM source, both B(a)P and total POM provide excellent indicators of hazard, evaluated by a weighted sum of concentrations. The method of using a linear combination of the masses of the individual POM compounds to model hazard due to POM is shown to be appropriate under certain conditions, and to follow directly from a simple probabilistic model of the physical and chemical events leading to a response event. While the assigned weights used in the linear combinations are only rough estimates of hazard for each compound (based on the present ranking systems), the weighting systems considered are sufficiently varied to suggest that the results will be at least as valid when based on future, more detailed knowledge of the potency of the individual components.

The results suggest that, in most cases, total POM measurements provide somewhat more consistent hazard prediction than those of B(a)P (though this is not always the case). This feature is reflected in a smaller variability of the prediction factor for total POM than for B(a)P when *different* POM generating sources are compared. In view of this, it is clear that the total POM indicator will be the more useful in predicting hazard for sources for which the compound-specific composition of POM emitted is not well known.

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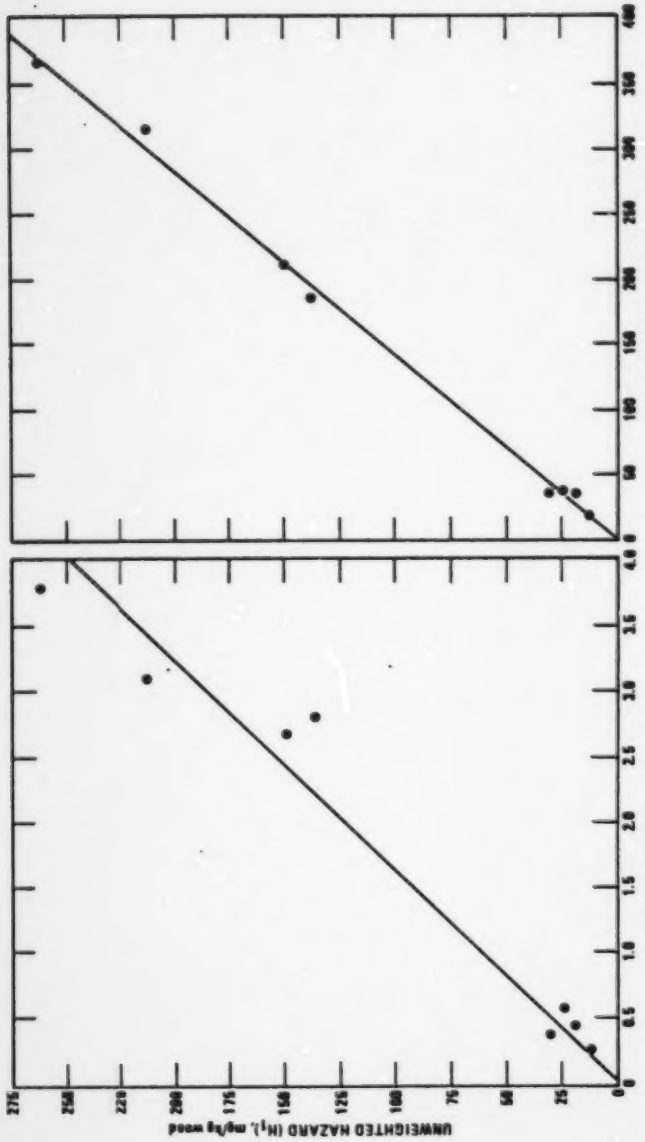

Figure 1. Unweighted hazard (H_1) vs. B[a]P concentration for study 1 (wood combustion emissions).

Figure 2. Unweighted hazard (H_1) vs. total POM concentration for study 1 (wood combustion emissions).

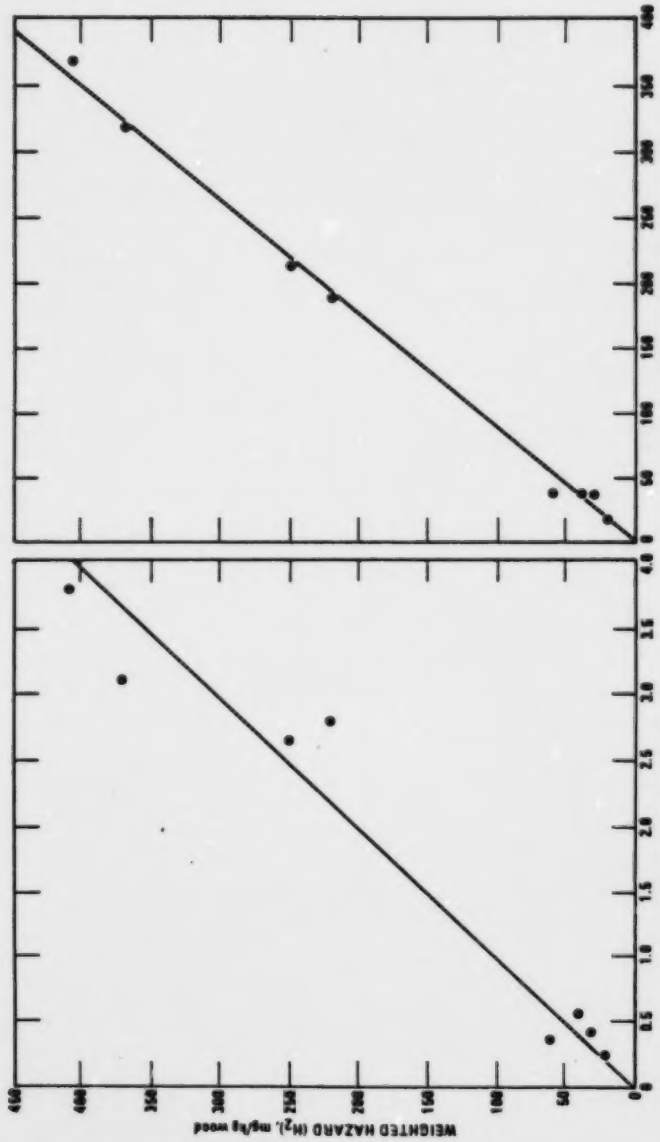

Figure 3. Weighted hazard (H_2, B(a)P weight = 4) vs. B(a)P concentration for study 1 (wood combustion emissions).

Figure 4. Weighted hazard (H_2, B(a)P weight = 4) vs. total POM concentration for study 1 (wood combustion emissions).

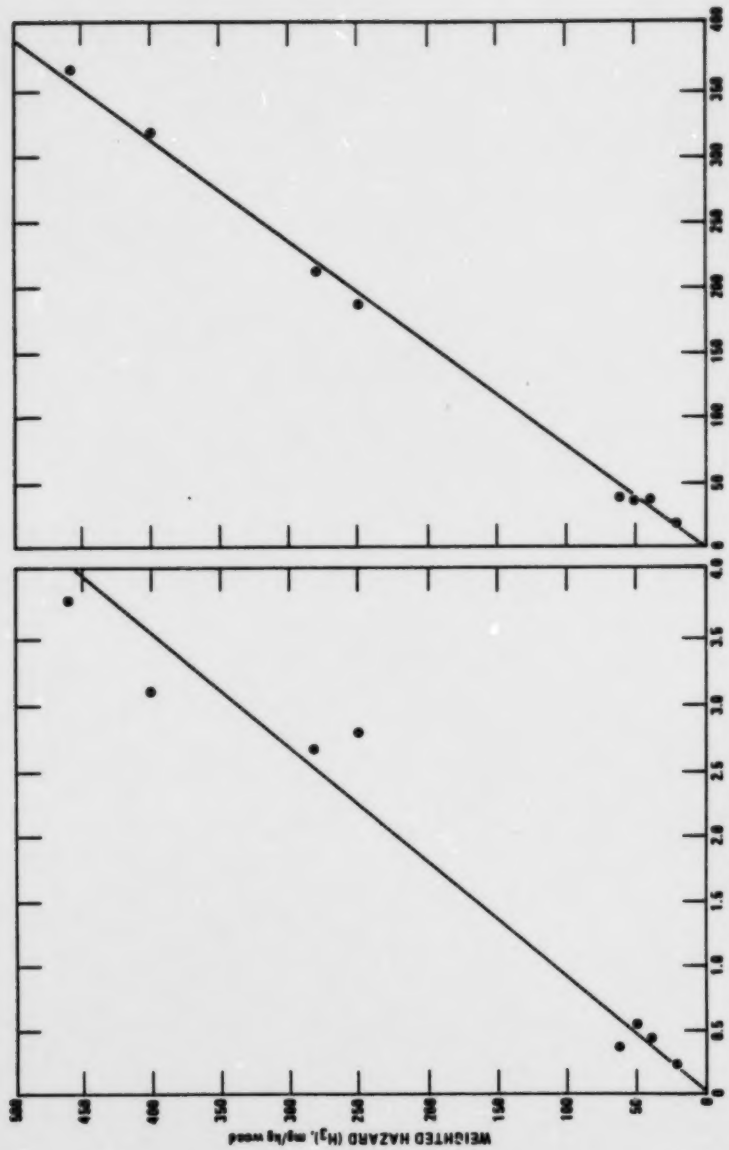

Figure 5. Weighted hazard (H_3, B(a)P weight = 16) vs. B(a)P concentration for study 1 (wood combustion emissions).

Figure 6. Weighted hazard (H_3, B(a)P weight = 16) vs. total POM concentration for study 1 (wood combustion emissions).

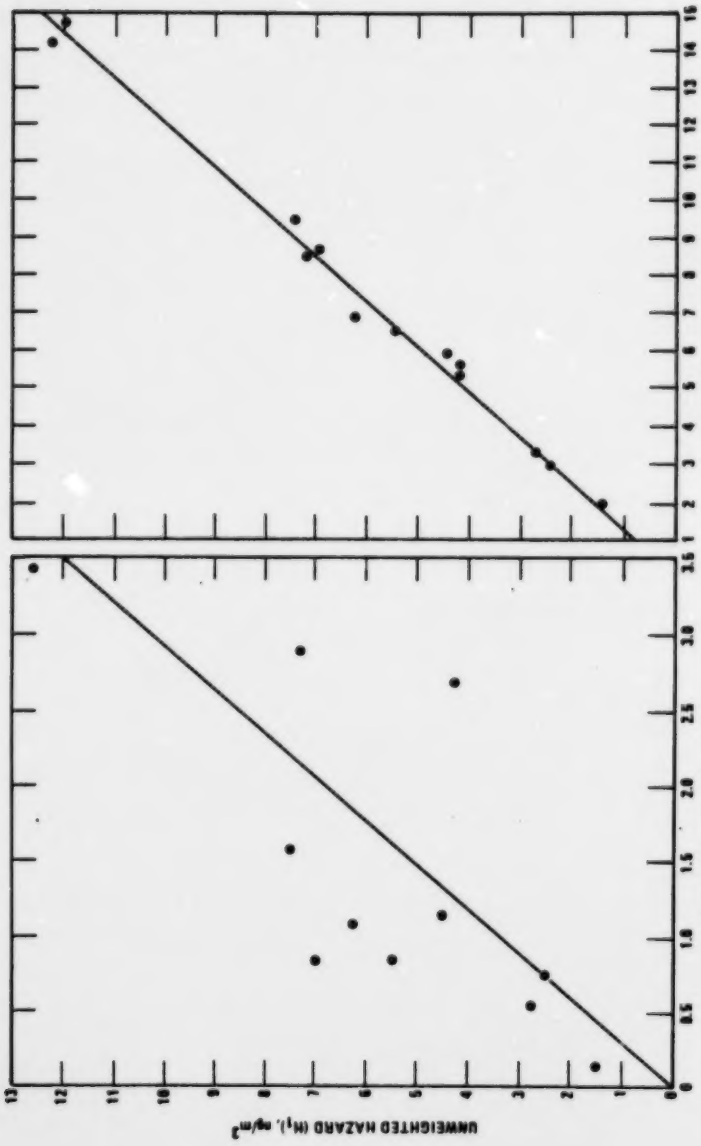

Figure 7. Unweighted hazard (H_1) vs. B(a)P concentration for study 6 (New York City atmosphere).

Figure 8. Unweighted hazard (H_1) vs. total POM concentration for study 6 (New York City atmosphere).

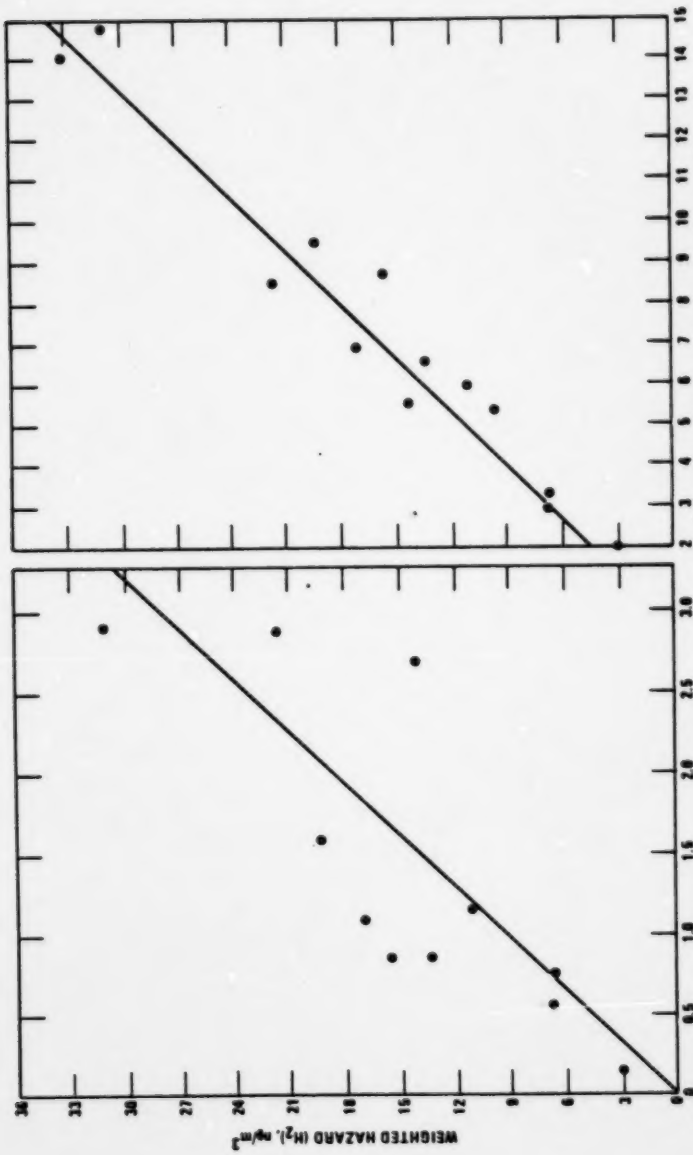

Figure 9. Weighted hazard (H_2, B(a)P weight = 4) vs. B(a)P concentration for study 6 (New York City atmosphere).

Figure 10. Weighted hazard (H_2, B(a)P weight = 4) vs. total POM concentration for study 6 (New York City atmosphere).

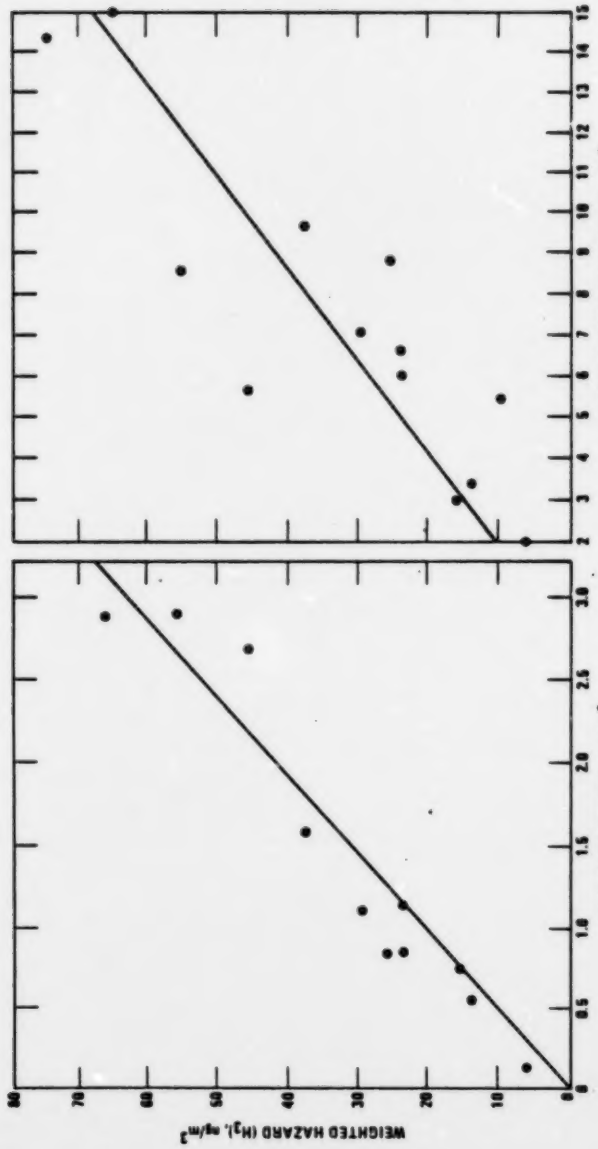

Figure 11. Weighted hazard (H_3, B(a)P weight = 16) vs. B(a)P concentration for study 6 (New York City atmosphere).

Figure 12. Weighted hazard (H_3, B(a)P weight = 16) vs. total POM concentration for study 6 (New York City atmosphere).